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US 3916148 A
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(54) Multiple power pulses in an impulse welding apparatus

(57) The invention comprises a heating process and apparatus defining a first higher power heating impulse from t_0 to t_1 immediately followed by a second lower power heating impulse from t_1 to t_2, optionally followed by a cooling phase. Clamping pressure on an array of plastic films to be sealed is maintained during the first and second heating impulses and the optional cooling phase. Preferably the voltage level during the first heating impulse is maintained at a first high level and the voltage level during the second heating impulse is maintained at a second lower level giving a temperature diagram (Fig. 6) involving obtainment of a peak temperature T_m at the end of the first heating impulse and maintenance of a temperature just above a second, lower temperature T_s in the second heating impulse, to allow adequate penetration of heat to the or each interface from the exterior of the array of film plies to be sealed. A heat sealing bar with a temperature coefficient of resistance of around $4500 \times 10^{-6}\Omega/°C$ may be used, causing the power to decrease through the first impulse as the temperature rises.

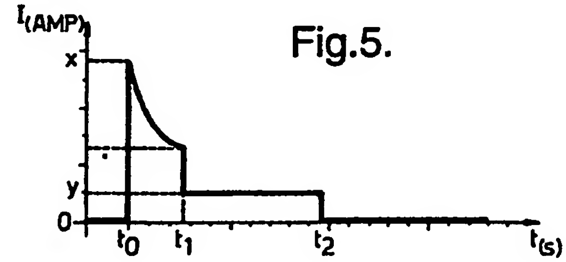

Fig.5.

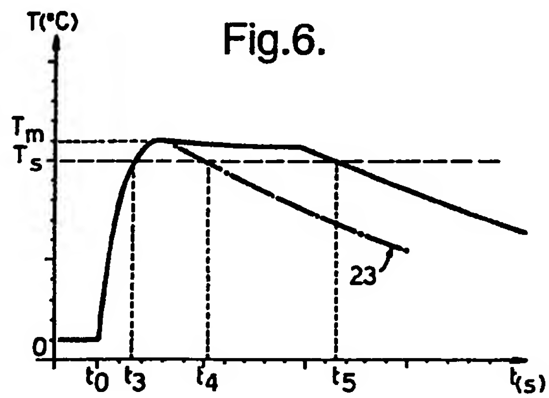

Fig.6.

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At least one drawing originally filed was informal and the print reproduced here is taken from a later filed formal copy.

Fig.1.

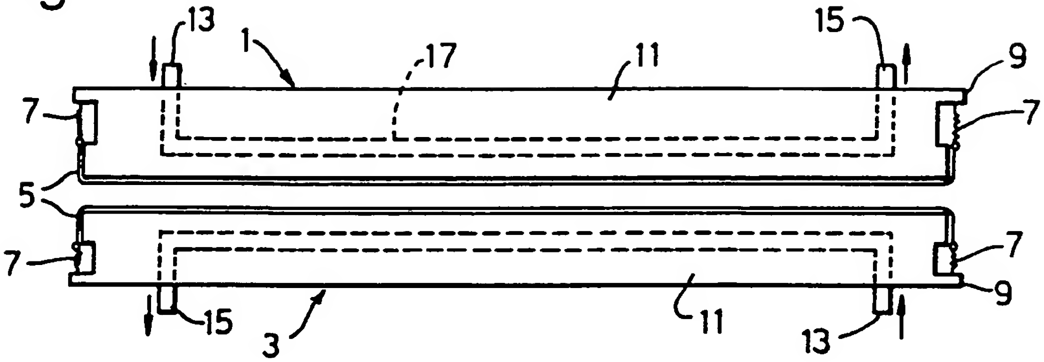


Fig.2.

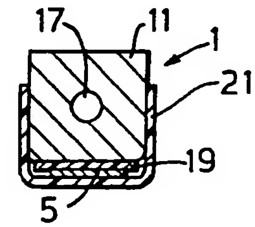


Fig.3.

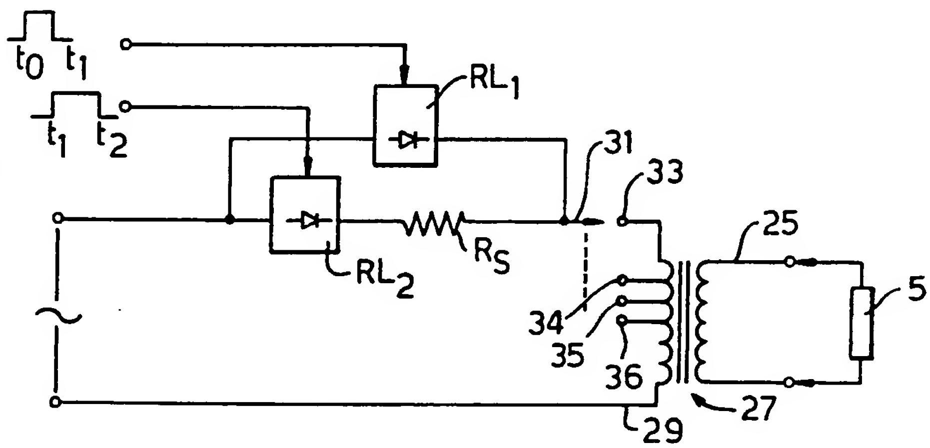
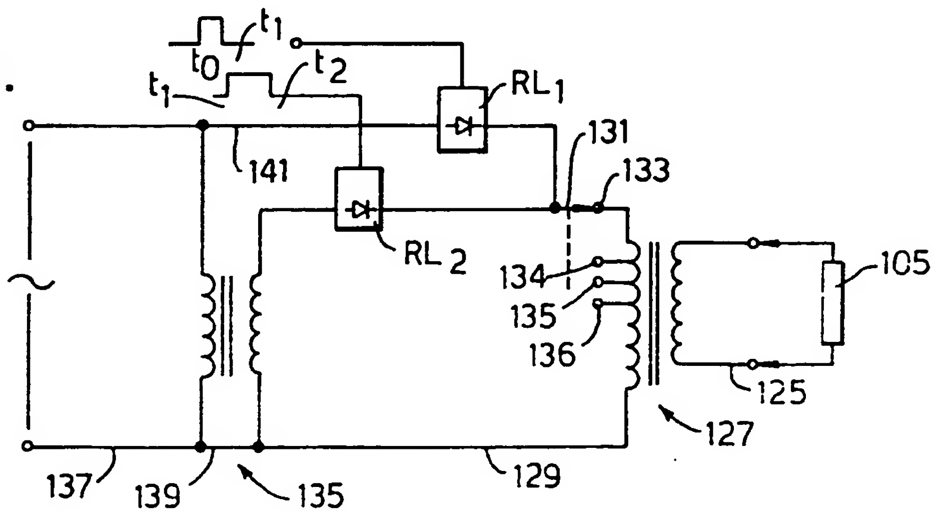


Fig.4.



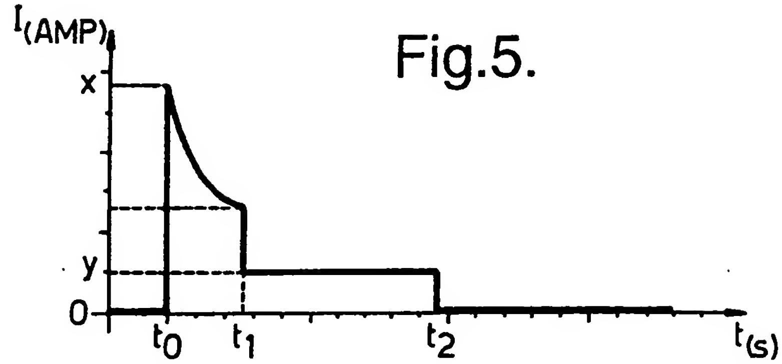


Fig.5.

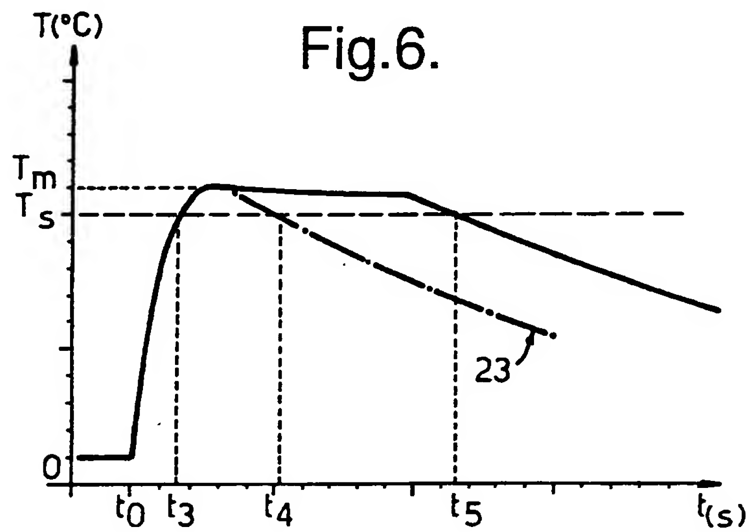


Fig.6.

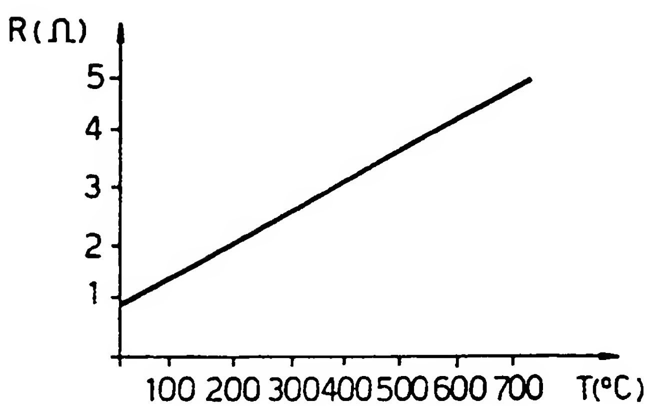


Fig.7.

Fig.8a.

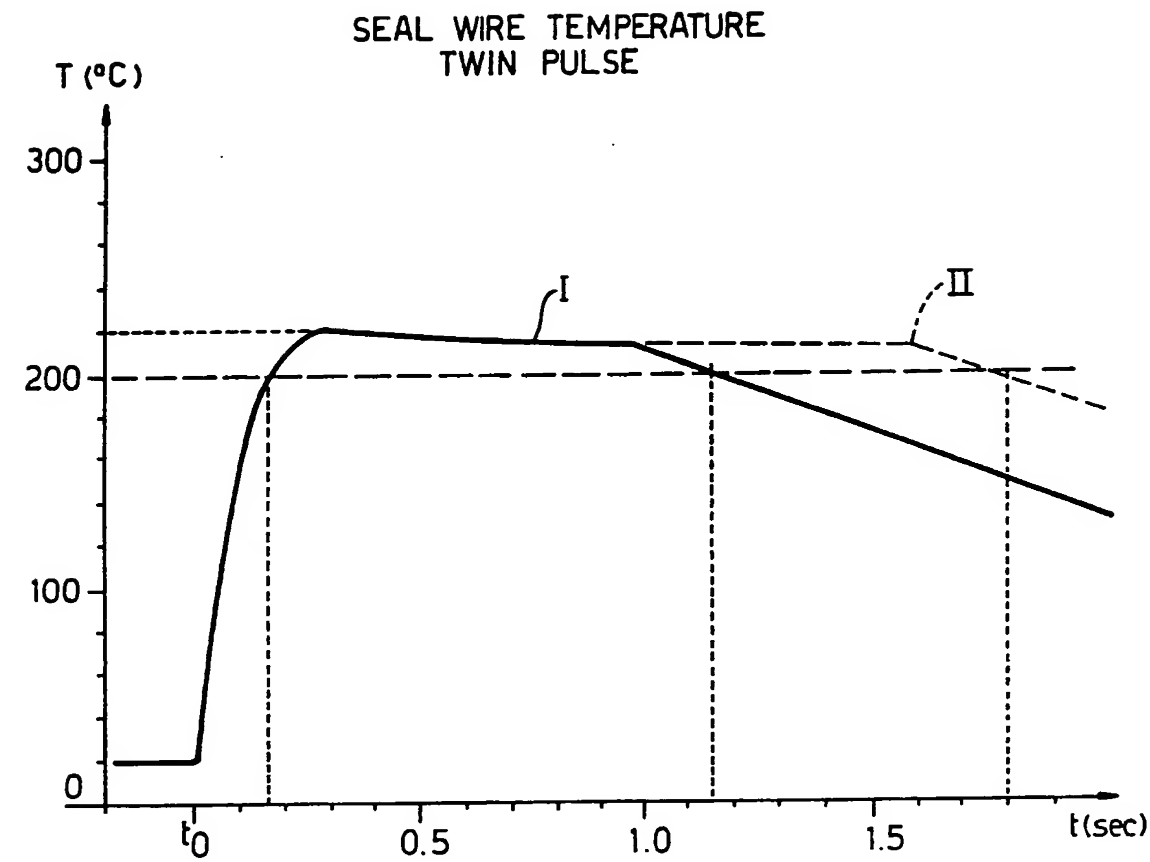

SEAL WIRE TEMPERATURE
TWIN PULSE
T (°C)
300
200
100
0
I
II
t0
0.5
1.0
1.5
t(sec)

Fig.8b.

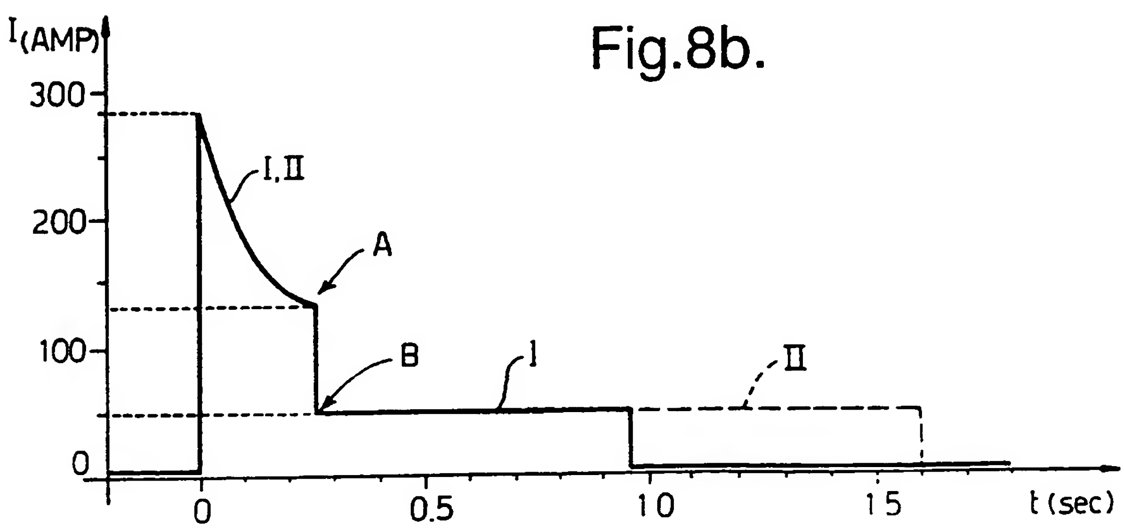

I(AMP)
300
200
100
0
I,II
A
B
I
II
0
0.5
1.0
1.5
t (sec)

Fig.9a.

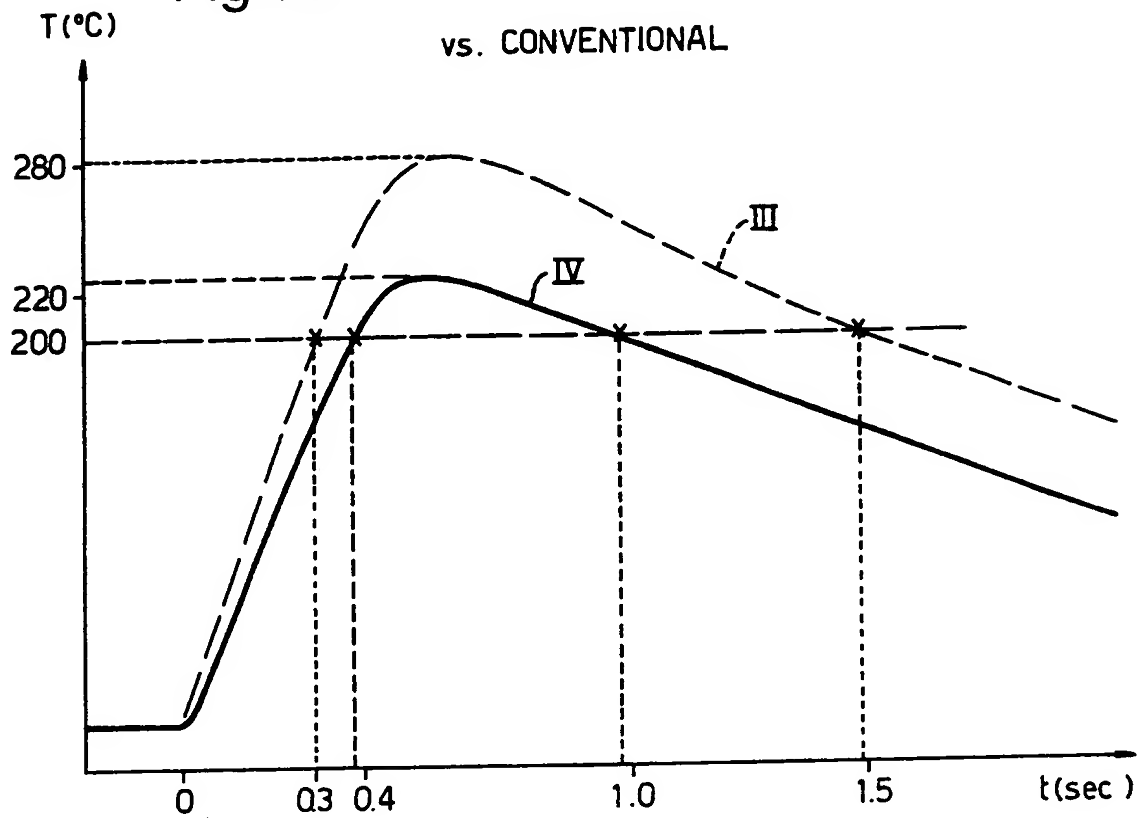

T(°C)
vs. CONVENTIONAL
280
220
200
III
IV
0
0.3
0.4
1.0
1.5
t(sec)

Fig.9b.

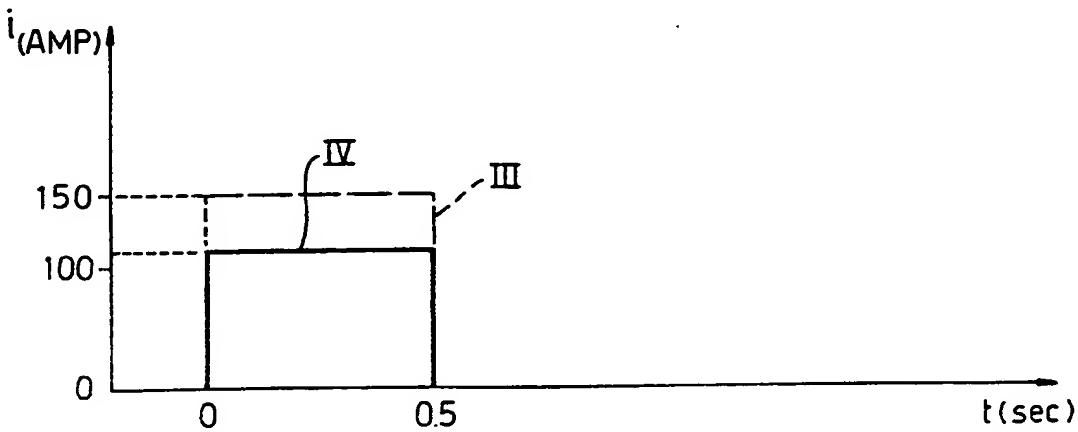

i(AMP)
150
100
0
IV
III
0
0.5
t(sec)

Fig.10a.

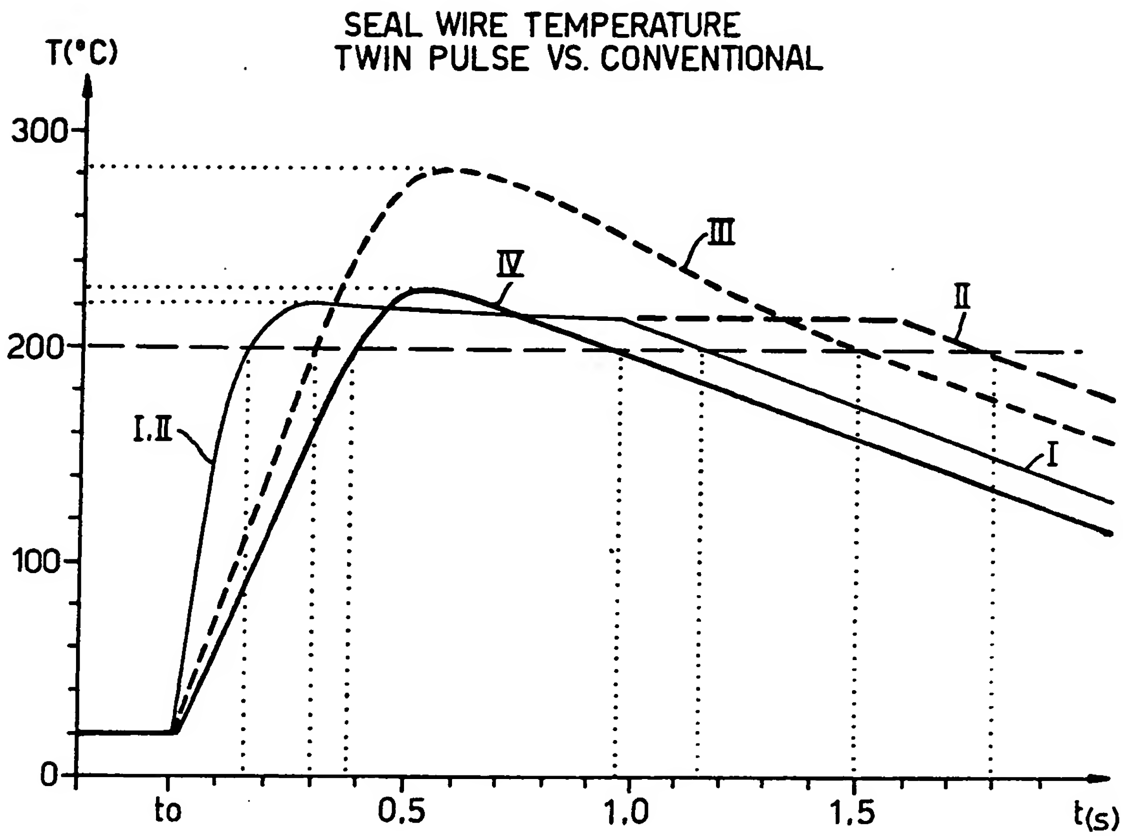


Fig.10b.

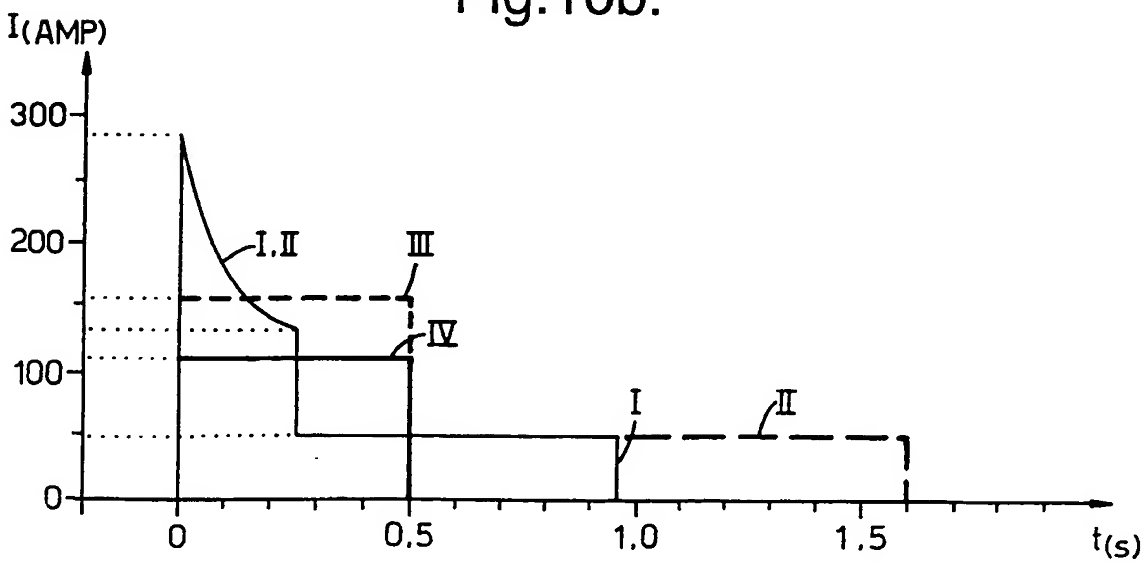


Fig.11a.

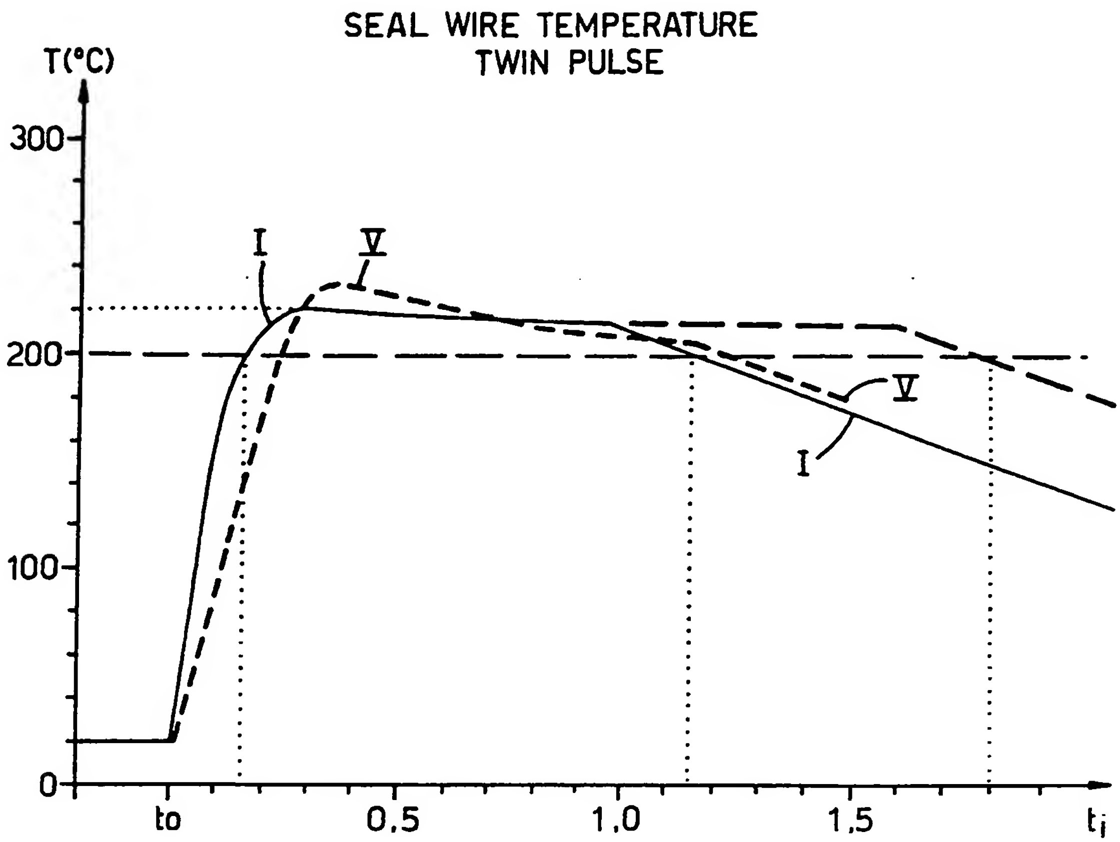
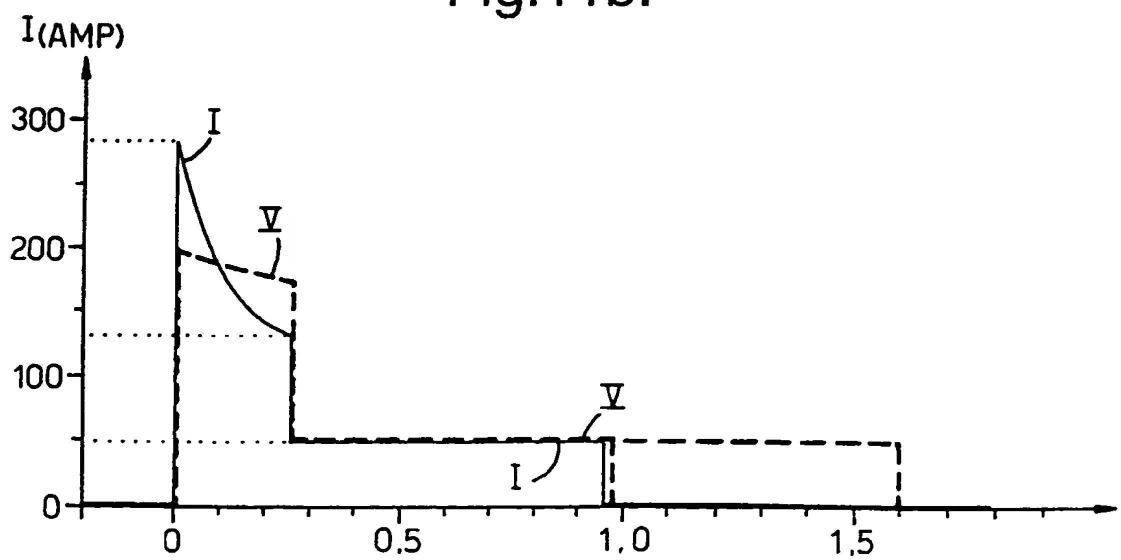


Fig.11b.



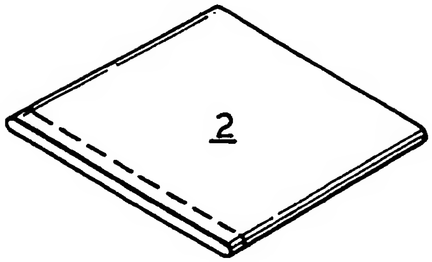


Fig.12a.

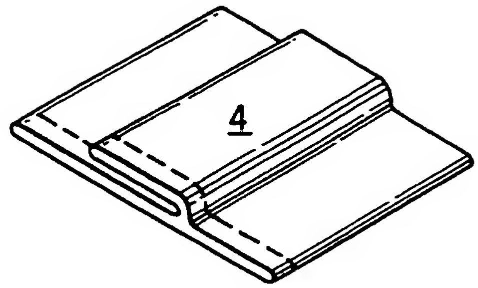


Fig.12b.

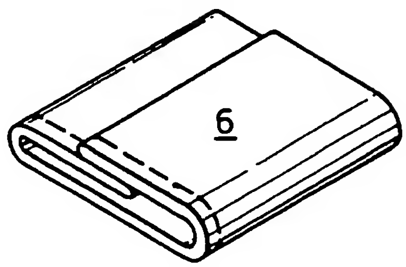
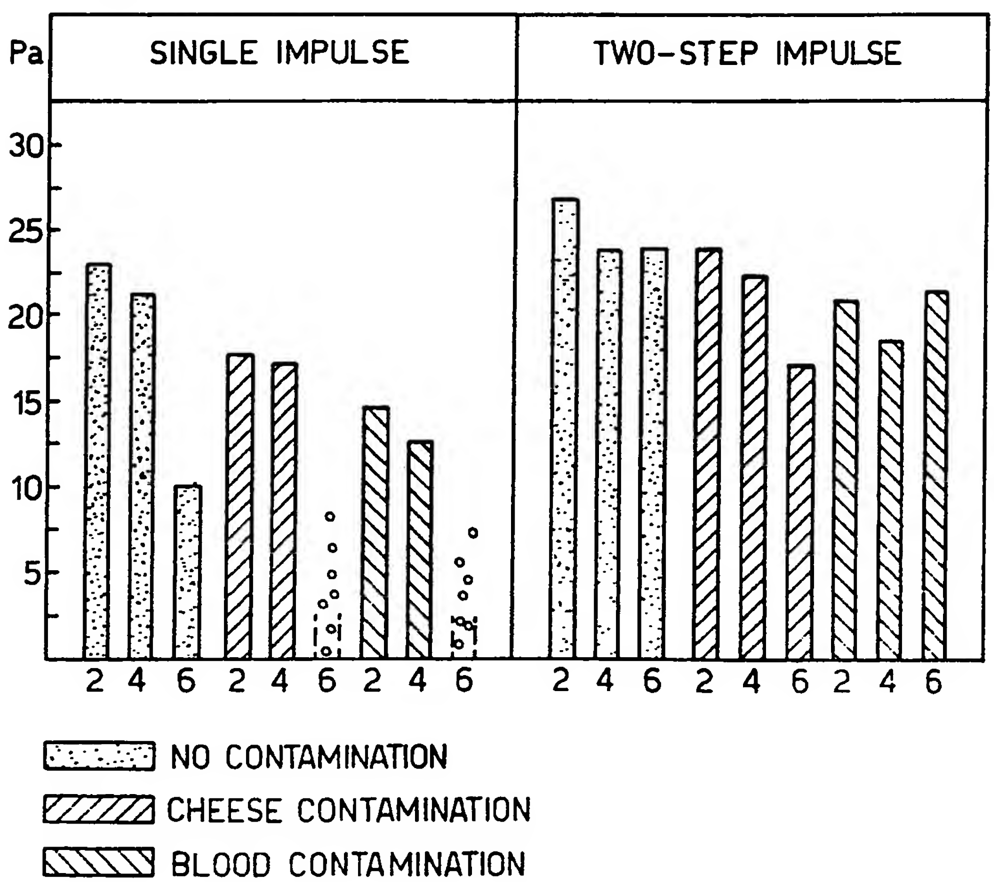


Fig.12c.

Fig.13.



HEAT SEALING APPARATUS AND PROCESS

The present invention relates to a method of and apparatus for heat sealing plastics material.

For a considerable time it has been the practice to seal layers of plastics material by a welding action involving applying heat to superposed plies of the material, so that the temperature is above the sealing temperatures of the various films and is below the degradation temperature of any of the films, in order to ensure that there is a reliable heat seal without damage to the film and contamination of the surface from which sealing heat is applied.

Conventionally, the surface is question is the plastic-contacting surface of a heat seal bar which has a heat seal member such as an electrically conductive wire or tape extending therealong and optionally includes a cooling passage for cooling medium to pass through the bar, after each electric heating impulse in order to avoid a cumulative build-up of heat and consequent overheating of the plastic-contacting surface of the bar.

Such a heat sealing apparatus may either comprise one such heated bar and an anvil with which it cooperates and in which the or a further cooling channel may be provided, or it may comprise two such heat sealing bars which clamp the plastic plies between them.

The heat sealing bar used for heating plastic films normally operates by virtue of a single heat impulse which is then followed by the above-mentioned cooling action, preferably while the bar is still in contact with the film in order to allow the films to cool gradually while maintained in clamped configuration to enhance the sealing action.

A double impulse heating action has been proposed in the past but in limited applications.

US-A-2766809 discloses a double impulse system in which the first impulse is effective to heat the heating element rapidly while the sealing jaws are spaced apart from the

film, in order to bring the temperature of the heating element rapidly to the selected heating temperature. When that sealing temperature has been reached, the jaws are then closed on to the plastic plies and a reduced power impulse is carried out controlled by a make-and-break microswitch action in response to expansion of the heating element.

US-A-2630396 discloses two successive heating impulses in which the first heating impulse applies the sealing heat and the second heating impulse is initiated as soon as the jaws begin to separate and this second impulse serves simply to guard against superficial adhesion between the sealed region of the (thermoplastic) plies and the surface of the heater element, in order to avoid weakening of the seal as the jaws separate.

A double phase heating action has been disclosed in US-A-5117613, but only in the context of induction heating and this will give rise to relatively slow heating actions as compared with the speed of heat sealing possible with a heat impulse sealing bar arrangement.

It is a drawback of the conventional heat sealing bar methods and apparatus that the temperature of the wire needs to be metered and controlled in order to ensure that it lies in the desired range from the highest sealing temperature to the lowest degradation temperature of the collection of films being sealed. Traditionally this requires a complex thermostatic, preferably electronic, control system to achieve the desired regulation of the heating current to maintain the temperatures in the desired range.

Accordingly, one aspect of the present invention provides a process for heat sealing thermoplastic film plies comprising clamping the film plies in contact with one another, between two clamping surfaces along a seal region; applying to at least one of the clamping surfaces a first electrical heating impulse of a first power level while maintaining the clamping action, in order to obtain a temperature which is at least equal to the sealing tempera-

ture (as hereinafter defined) of the film plies to be sealed, and less than the degradation temperature of the film; then immediately applying a second electric heating impulse of a second power level less than said first power level, to maintain a temperature which is at least as great as said sealing temperature again while maintaining the clamping action; and releasing the clamping action by separating the clamping surfaces from one another.

A second aspect of the present invention provides heat sealing apparatus comprising at least one heat seal bar having an electroconductive heating element; electrical charging means for said at least one heat seal bar; and a control circuit defining for said electrical charging means a first heating impulse at a first power level, immediately followed by a second heating impulse at a second power level less than first power level; and means for clamping an array of thermoplastic film plies to be sealed, in contact with said at least one sealing bar during said first and second heating impulses.

A third aspect of the invention provides a heat sealing bar having an electroconductive heating element having a temperature coefficient of resistance which is at least 200 x 10^{-6} Ω/°C.

The term "sealing temperature" as used herein is intended to denote the lowest temperature to which the film can be heated and still achieve a seal at the film interfaces.

In order that the present invention may already be understood that following description is given, merely by example, with reference to the accompanying drawings in which:-

Fig. 1 is a side elevational view of a pair of heat sealing bars which can be controlled in accordance with the method and apparatus of the present invention;

Fig. 2 is a cross section through the upper sealing bar of Fig. 1;

Fig. 3 is a schematic circuit diagram of one form of control circuit for the sealing apparatus in accordance with the present invention;

Fig. 4 is a schematic circuit diagram of a second embodiment of control circuit for use with the present invention;

Fig. 5 is a diagram plotting the heating current in the sealing wire against elapsed time in the sealing cycle;

Fig. 6 is a plot of the temperature of the sealing wire against elapsed time in the sealing cycle;

Fig. 7 is a resistance/temperature characteristic for the heating wire used in the seal bars of Figs. 1 and 2;

Fig. 8a is a plot of the sealing wire temperature against time during a sealing cycle in accordance with the present invention;

Fig. 8b is a plot of the sealing current against time, corresponding to the temperature/time plot of Fig. 8a;

Fig. 9a is a plot of the sealing wire temperature against time for two different conventional heating cycles using a single heating impulse followed by a cooling phase, the two heating impulses being of the same duration but of different amplitudes;

Fig. 9b is a plot of the sealing current against time for each of the two cycles illustrated in Fig. 9a, against the same time base;

Fig. 10 is a view showing the two conventional heating impulses of Fig. 9a superimposed on the same time base with the temperature/time plot of Fig. 8a;

Fig. 10b similarly illustrates all three of the current/time plots of Figs. 8b and 9b superimposed on the same time base;

Fig. 11a is a temperature/time plot of three separate heat sealing cycles in accordance with the present invention, showing the results when different temperature coefficients of resistance are used;

Fig. 11b is a plot of sealing current against time for

the same three heating cycles shown in Fig. 11a, on the same time base;

Fig. 12a is an illustration of the film configuration used for Example 1 where a two ply build up extends along the whole seal line;

Fig. 12b is an illustration of the film configuration used for Example 2 where the film has been folded to provide four plies to be sealed in the centre of the seal line and two plies towards the ends of the seal line;

Fig. 12c is an illustration of an alternative folding in which there are six plies to be sealed at the centre of the fold line and four towards the ends of the fold line; and

Fig. 13 illustrates the seal strength in terms of bursting pressure results for the tests reported in Examples 1 to 8.

In Fig. 1 the sealing apparatus comprises an upper sealing bar 1 and a lower sealing bar 3, each comprising an aluminium body 11 supporting a heating ribbon 5 held in place under tension by springs 7 mounted between the ends of the ribbons 5 and projecting tongues 9 of the respective bodies 11 of the sealing bars. Additional insulation layers are incorporated along with the heating ribbons 5 as will be evident from Fig. 2 to be described below.

The heating ribbon 5 of the heating bar is formed of an electroconductive material, for example a high temperature coefficient of resistance alloy of iron and nickel, such as that marketed as Hytemco available from the Driver-Harris Company of New Jersey, USA.

Although in Figs. 1 and 2 the heating element 5 is in the form of a ribbon, it could instead be of other construction, for example a wire, such as a circular cross-section wire.

As shown in Fig. 1, each of the seal bar bodies 11 includes a coolant inlet 13 and a coolant outlet 15 for flow of a cooling medium such as water through a coolant conduit

17 extending longitudinally through the aluminium body 11.

Fig. 2 shows that underlying the metal heating ribbon is an insulating strip 19 capable of withstanding the temperatures to which the ribbon 5 is, in use, heated, and providing electrical insulation between the ribbon 5 and the aluminium body 11 of the heating bar.

Furthermore, covering both the heating ribbon 5 and the insulation layer 19 is an outer non-stick covering layer 21 of polytetrafluoroethylene fabric, in order to prevent build-up of deposit of the plastic material of the sealed film plies on the surface of the sealing bar 1 or 3, and also to avoid any tendency for the seal to be torn open as the upper and lower sealing bars 1 and 3 separate from one another, or as the upper sealing bar 1 separates from a fixed anvil in the alternative case where one heated movable sealing bar cooperates with an anvil.

In accordance with the present invention the heating cycle consists of a first high power impulse in which the temperature of the sealing ribbon 5 or wire is rapidly raised by an electrical impulse to a temperature at least equal to the sealing temperature of the thermoplastic film plies to be sealed (or the highest sealing temperature where several different materials are to be sealed) but yet below the degradation temperature of the film. In this way it is possible to ensure that sealing will occur at a temperature which is achieved very rapidly and which will not prejudice the integrity of the film being sealed.

For attainment of this initial high temperature there is a first heating impulse at a relatively high power level as compared with a second impulse or phase to follow, and during the first impulse the heating from the heat sealing bar is able to penetrate rapidly through the build-up of thermoplastic plies to be sealed, but because of the relatively high power level involved this first impulse is short lived to guard against overheating of the clamped films.

A second, lower power level, electric impulse is

applied to the heat sealing ribbon or wire to maintain the temperature of the heating element at least equal to the sealing temperature of the films, and during this "dwell" period the application of heat to the plastic film plies continues but at a level which is sufficiently low as to be well clear of the degradation point of the films. Nevertheless during this second impulse heat is able to penetrate still further into the build-up in order to ensure that at every interface the temperature has achieved at least the sealing temperature of the films plies, in order to build a good bond at the interfaces.

After these first two "heating impulse" phases there follows an optional cooling phase during which the bars or bar and anvil maintain clamping pressure on the film plies while the clamping surfaces are cooled, for example by cooling water in the coolant conduits 17.

Although in theory it is expected that there will be simply one interface between any two film plies to be sealed, it must be borne in mind that in practice it may be difficult to ensure that the film plies lie absolutely flat on one another and there may be some wrinkling occurring inadvertently, or even some deliberate localised doubling over of films where, for example during the manufacture of plastic bags, there are some regions along a seal line where only two plies are being sealed and others where the film may be doubled over on itself more than once thereby giving rise to a multiple ply build-up of more than two plies.

The process and apparatus in accordance with the present invention have been found particularly useful in the context of sealing where there is a variation in the film thickness along the common seal line. In those areas where only a few plies are superimposed there is no risk of degradation of the films at the internal interfaces (which, as shown in Fig. 9a, could occur if an initially high temperature were attained in order to ensure adequate propagation of heat to those internal interfaces) although

degradation of the plies (especially outer plies) is still a concern so appropriate selection of temperature is necessary to ensure that while adequate sealing occurs in those areas where there are more than two plies being sealed no degradation arises.

A plot of the sealing current (i) measured in amps, with respect to the cycle time of the sealing cycle, measured in seconds, is shown in Fig. 5. Starting from the origin O of this plot, corresponding to the start of the sealing cycle, there is a time interval up to time t_0 during which the seal bars close together (or the single seal bar closes on to the anvil). At time t_0 an initial current pulse of the first duration is started, and this lasts until t_1. A typical value for the first time interval (t_1-t_0) is from 0.2 seconds to 1 second).

During the second impulse of the heating phase, lasting for a second duration from time t_1 to t_2 a reduced power level is maintained so that the temperature is still just in excess of the sealing temperature of the build-up of film plies (or the highest sealing temperature where various different film materials are used).

The temperature plot of the double impulse heating operation illustrated in Fig. 5 is shown in Fig. 6 where the temperature(T) in degrees Celsius is plotted against the time(t) in seconds.

The onset of degradation is avoided by setting a maximum temperature T_m (see Fig. 6) at the end of the first heating impulse shown in Fig. 5. The sealing temperature is shown as T_s and is just exceeded (see Fig. 6) by the temperature throughout the second heating impulse of Fig. 5.

The initial attainment of the sealing temperature T_s is shown on Fig. 6 as time t_3, as the temperature rises to its maximum value T_m (reached at time t_1) and the point at which the temperature, decaying during the cooling phase after the end of the second heating impulse of Fig. 5, reaches the sealing temperature T_s is marked on Fig. 6 as time t_5.

If the resistance of the heating strip 5 were to remain constant with varying temperature, then a constant voltage in the first heating impulse between t_0 and t_1 would give rise to a constant current x, and likewise a constant lower voltage in the second heating impulse between t_1 and t_2 would give rise to a constant current y in that heating impulse. However, in practice, the resistance does vary with temperature and a typical value of the temperature coefficient of resistance is that for the well known nickel-chromium alloy known as Nichrome 50 for which the temperature coefficient of resistance is 170×10^{-6} Ω/°C. This will therefore mean that the slope of the current/time plot on Fig. 5 would be less than that shown for the above-mentioned Hytemco alloy having a temperature coefficient of resistance of 4500×10^{-6} Ω/°C. This much greater temperature coefficient of resistance gives rise to a rapid reduction in current from peak value x to a value at time t_1 at the end of the first heating impulse.

By appropriate choice of the current amplitude in each heating impulse, in relation to the resistance and the temperature coefficient of resistance of the heating ribbon, the duration (t_1-t_0) of the first heating impulse can be shortened and the value of the temperature throughout the second heating impulse from t_1 to t_2 can be maintained substantially constant for a constant current.

In Fig. 6 the dot-dashed plot 23 shows how the temperature would continue to drop if only a single heating impulse were to be used. The much more favourable retention of temperature above the sealing temperature T_s in Fig. 6 gives rise to an ability to impart heat at a safe intensity to a much greater depth in the build-up of thermoplastic plies to be sealed, when using the double impulse heating system proposed in accordance with the present invention.

T_s is assumed to be the wire temperature required in order to achieve an adequate seal. The time during which the heat at wire temperature T_s is allowed to propagate through the plastic material is from t_3 to t_5 and during this period

the peak wire temperature (which has a considerable influence on the useful working life span of a seal bar) only reaches T_m which is still lower than the degradation temperature of the film to be sealed.

As a comparison, a conventional single impulse sealing system using an impulse of duration (t_1-t_0) will exceed the temperature T_s in the sealing area only during the interval from t_3 to t_4 shown in Fig. 6 and fall below it after time t_4]. This is evident from the "single impulse" curve continuation 23.

Fig. 7 illustrates the resistance/temperature characteristic for the nickel-iron alloy Hytemco, with the resistance plotted in Ω and the temperature in degrees Celsius.

In the prior art it has been necessary to incorporate a monitoring of the temperature of the heating strip 5 and also a careful control of the heating power to ensure that the temperature does not exceed the temperature T_m and yet does manage to lie in the range T_s and T_m. This has in practice been achieved by adjusting the voltage so that the ensuing current in the heating strip 5 is commensurate with the appropriate power to keep the temperature in the desired range from T_s to T_m.

The use of a double heating impulse in accordance with the present invention, particularly with an alloy having a high temperature coefficient of resistance (i.e one having a value of greater than 200×10^{-6} Ω/°C) used for the heating strip 5 allows a much more simple circuit without the need for detailed electronic control. Two forms of such circuit are illustrated in Figs. 3 and 4.

In Fig. 3 the heating strip 5 is connected in the secondary 25 of a step-down transformer 27. The primary 29 of this step-down transformer is energising by mains ac and has a parallel network of a first branch comprising a solid state relay RL_1 and a second branch comprising a solid state relay RL_2 in series with a resistor R_s.

The two solid state relays RL_1 and RL_2 are zero crossing

relays and are actuated by a programmable logic controller (PLC), not shown, with a square wave input impulse shown alongside the gating conductors of each of the relays. It is clear from these illustrations that the relay RL_1 is caused to define the first heating impulse in the time period from t_1 to t_2, whereas the second relay RL_2 is caused to define the second time period from t_1 to t_2.

The primary 29 of the step-down transformer 27 includes a selective connecting conductor 31 which can be connected to any one of several taps 33, 34, 35 and 36. When connected to the tap 33, as shown, the voltage across the heating strip 5 is at its maximum, whereas a set of reduced values is possible by selecting appropriate one of the further taps 34, 35 and 36 for the conductor 31.

During operation the electroconductive heating strip 5 is energized during the first heating impulse by gating of the relay RL_1, with ac at a voltage selected in accordance with the appropriate one of the taps 33 to 36 which is connected to the conductor 31.

During the second heating impulse the voltage is depressed by virtue of the additional resistance R_s in series with the second relay RL_2.

After time t_2 both relays RL_1 and RL_2 are caused to close the primary 29 of the step-down transformer 27 and a cooling phase ensues as coolant is passed through the conduit 17 of the or each cooling bar 11 through the inlet 13 and outlet 15 thereof.

After an appropriate duration of the cooling phase the jaws are driven to open and the machine cycles to remove the sealed film plies and to introduce a fresh set of film plies to be sealed, whereupon the next sealing cycle starts and the jaws close during the period (from 0 to t_0).

The circuit shown in Fig. 4 is substantially the same as that of Fig. 3, and those components which are common to the two circuit diagrams are referenced in Fig. 4 by numerals increased by 100 over the corresponding reference numerals of

Fig. 3.

In Fig 4 the primary to the step-down transformer 127 includes a supply transformer 135 whose secondary is connected in series with the primary coils of the step-down transformer 127 and with the second gating relay RL_2. The primary 137 of the supply transformer 135 is connected to mains ac, but additionally includes conductors 139 and 141 to the primary of the step-down transformer 127. The conductor 141 includes the first zero crossing solid state relay RL_1 to define the time period between t_0 and t_1 and in which case the full primary voltage of the transformer 135 (ie mains voltage) is applied across the chosen number of primary turns of the step-down transformer 127, whereas in the second heating impulse between t_1 and t_2 the first gating relay RL_1 interrupts the flow in conductor 141 but the second gating relay RL_2 in the secondary of the supply transformer 135 is gated to conduct between the secondary of the supply transformer 135 and the primary turns of the step-down transformer 127, the turn ratio of the supply transformer 135 being chosen such that there is a step-down in voltage, between the primary 137 of transformer 135 and the primary 129 of the step-down transformer 127, commensurate with the required difference in voltage between the first heating impulse and the second heating impulse.

As an example of the efficacy of the method and apparatus in accordance with present invention the following examples are given:-

Example 1.

A flat-folded tube of a heat-sealable film of a thermoplastic film material was clamped flat between the heat seal bars of a Cryovac VC14 vacuum chamber machine available from W R Grace & Co - Conn. and the conventional single impulse cycle was carried out, with a cycle duration of 8 seconds comprising a 3 second heating impulse and a 5 second cooling down step. The seal strength was measured in terms of a variable pressure hot burst test result. The configuration

of the film tube is illustrated in Fig. 12a.

The variable pressure hot burst (VPHB) test referred to above involves forming a transverse seal across a tube of plastic material (folded as illustrated in Figs. 12a, 12b and 12c for the respective tests) and testing the strength of that seal by inflating the tube to one side of the seal with a base line inflation pressure of about 3000 Pa. In the tests the transverse seal was used to form a bag 250 mm wide x 400 mm long.

The thus inflated bag was then immersed in water heated to 85°C and held immersed for 5 seconds;

Then the inflation pressure is increased at a specified rate of 249 Pa/sec (1" H_2O/sec).

This is a standard seal strength evaluation test and the standard test equipment allows a variation of the rate of increase of inflation pressure within the range of 249 Pa (1 inch water gauge) to 1743 Pa (7 inches water gauge) per second. The pressure at which the seal fails by bursting of the bag is noted, and this bursting pressure is recorded on the bar graph of Fig. 13.

In some cases the seal was so poor that the bag inflated at the base line pressure of 3000 Pa failed immediately upon immersion. Otherwise the inflation pressure is correctly represented by the bar graph.

<u>Example 2</u>.

Example 1 was repeated, except, that the tube was pinched along its length and folded over, as illustrated at Fig. 12b, resulting in 4 plies of film to be sealed near the centre of the seal line and 2 plies away from the centre. The bursting strength of the seal is shown in the second bar of Fig. 13 as having a value of 21 KPa.

<u>Example 3</u>.

Example 1 was repeated, but with the two marginal parts of the tube folded over towards the centre so as to overlap in the central region, as shown as Fig. 12c. This gave 6 plies to be sealed at the centre and 4 plies to be sealed

away from the centre of the seal line. The result of 10 KPa is plotted on the third bar of Fig. 13.

Example 4.

Examples 1, 2 and 3 were each repeated, but this time with cheese contamination on the surfaces of the films at the seal line. The results of these three tests are plotted in the 4th, 5th and 6th bars on Fig. 13, although the bursting strength obtained with this "cheese contaminated" re-run of example 3 (the 6th bar on Fig. 13) is so poor that the seal burst immediately upon immersion so bubbles were observed in the tank and are shown graphically on the 6th bar of Fig. 13.

It is evident that with the cheese contamination there is little loss in performance between the 2 ply and 4 ply seals, whereas the 6 ply seal is distinctly worse than either of them. However the contamination has in any case given a deterioration of the 2 ply and 4 ply results from 23 KPa and 21 KPa, respectively, to 17 and 16.7 KPa, respectively.

Example 5.

The tests of example 4 were re-run, but this time with animal blood contamination rather than cheese contamination on the seal lines. The results are plotted in the 7th, 8th and 9th bars on Fig. 13 and again there is an illustration of bubbles in the "6 ply" result indicating failure immediately upon immersion. In this case there is a distinct deterioration from 14.4 KPa down to 12.4 KPa when increasing from 2 plies to 4 plies to be sealed.

Thus far the tests are all to show the loss in performance experienced with a conventional single impulse heating system when increasing the number of plies and when encountering contamination of the film to be sealed.

The results in accordance with the present invention were obtained with the following three examples:-

Example 6

The control circuit of the Cryovac VC 14 vacuum chamber machine was modified as shown in Fig. 3 in order to provide the twin heating impulse cycle in accordance with the present

invention.

With a machine thus modified, and with clean film plies, examples 1, 2 and 3 were repeated and the results are plotted in the 10th, 11th and 12th bars of Fig. 13. As can be seen, the 2 ply result is improved still further over 2 ply result with the single impulse system in that a value of 27 KPa bursting pressure was obtained.

A more noticeable increase occurred with the 4 ply and 6 ply results using the double impulse system in that the results were equal, showing no deterioration when advancing from 4 plies to 6 plies, at 23.7 KPa. In terms of the 6 ply result shown in the 12th bar of Fig. 13 this represents an improvement of over 100% as compared with the inadequate result shown on the 3rd bar of Fig. 13.

Example 7

The three tests of example 6 were repeated, but this time with cheese contamination on the seal lines of the superposed thermoplastic film plies to be sealed. Here the results are still more dramatic in that while there is a slightly greater difference between the 2 ply and 4 ply results with the double step impulse cycle as represented at 23.7 KPa and 22 KPa respectively in the 13th and 14th bars of Fig. 13, the 6 ply result gave a positive value of 17.2 KPa in the 15th bar of Fig. 13 as compared with the very poor result in the 6th bar of Fig. 13 for the single impulse result.

Example 8

The test of example 7 was repeated but with animal blood contamination on the film surfaces. Here a more surprising result ensued in that the bursting strength for the 6 ply test gave a value of 21.4 KPa which is better than any other of the blood-contaminated results for either the single impulse or double impulse tests (see the 18th bar on Fig. 13). By comparison the 2 ply result illustrated in he 16th bar in Fig. 13 was 21 KPa (still way in excess of the value of 14.5 KPa for the single impulse 2 ply blood-contami-

nated result shown in the 7th bar on Fig. 13) whereas the 4 ply blood-contaminated double step impulse result of 18.4 KPa as shown in the 17th bar of Fig. 13 is nonetheless distinctly better than the corresponding value of 12.7 KPa for the single impulse 4 ply result (shown in the 8th bar in Fig. 13).

The bar chart of Fig. 13 shows at a glance that there is much greater uniformity of the results for both the blood contaminated film and the cheese contaminated film in the double impulse results of tests 7 and 8 as compared with the corresponding results on test 5 for the single impulse, and likewise there is closer uniformity of the results for the cheese-contaminated double impulse results of test 7 than in the corresponding bars of test 4 for the single impulse result.

Given the fact that in practice it is difficult to avoid contamination of the mouth of a plastic bag as a block of cheese or a meat product is introduced into the bag (through the mouth and hence with some degree of contact with the interior of the bag neck), the practical value of the present invention in providing improve results when contamination is present it is particularly great.

Furthermore, the fact that the double impulse 6 ply results in the 15th and 18th bars of Fig. 13 are so much improved on the corresponding results shown at the 6th and 9th "bubbled" bars for the single impulse results provides another valuable testimony as to the improvement of the present invention.

Although in the above discussion of Fig. 13 we have attempted to compare the results with the single impulse and double impulse heating action, and those with and without various types of contamination, so as to show that the present invention does provide a distinct advantage, it must be borne in mind that the tests involved the need to modified other parameters to some extent so whereas the results give a good indication of the considerable improvements offered by

the present invention, a direct mathematical comparison between them should not be attempted.

Throughout the above description we refer to a thermoplastic film to be sealed, without mention of the possible shrink properties of that film. The present invention has been found to be capable of giving the same advantages when used on a shrink film as when used on a non-shrinkable film.

With the prior art single impulse system it was customary for the single heating impulse to last from 0.5 to 3 seconds, and for the ensuring cooling impulse to last from 1.5 to 5 seconds. With the double heating impulse of the present invention it has been found that the overall pulse duration may be from 0.7 seconds (a 0.2 second first impulse and a 0.5 second second impulse) to 4 (1 second first impulse and a 3 second second impulse) hence considerably shortening the heating period of each cycle such that it was possible to achieve improved results with a 3 second sealing cycle comprising 1st and 2nd heating impulses of 0.6 seconds each and a cooling phase of 1.8 seconds.

Figures 8a, 8b, 9a, 9b, 10a, 10b, 11a and 11b are all based on the use of Hytemco wires mounted on a Furukawa VR8620 rotating vacuum chamber machine whose operating cycle was modified for Figures 8a, 8b, 11a and 11b to operate in the double impulse heating mode. The sealing bars were all 450 mm in length.

Figure 8a shows the actual plot I of sealing temperature against time with a wire of Hytemco alloy having a temperature coefficient of resistance of 4500 x 10^{-6} Ω/°C, and the current/time plot for the same sealing wire, shown in Fig. 8b shows that the sealing cycle comprises a first impulse of approximately 0.25 seconds during which the sealing wire attained its maximum temperature of 220°C, followed by a second heating impulse of 0.7 seconds during which the temperature decays only slightly down to of the order of 208°C, due to the maintenance of heat input through

the second heating impulse at a lower power level than the first heating impulse. During this second heating impulse there is time for the heat input to the seal to propagate through the build-up of plastic material to reach each internal interface in order to form a secure bond at the internal interfaces. Because the temperature is maintained at approximately the peak temperature of 210°C, which will be above T_g but below T_m for the particular film plies being sealed, the external surfaces of the build-up of film plies to be sealed will not suffer degradation. The result is therefore a reliable seal with best quality freedom from contamination on the finished build-up.

The dotted line plot II in Fig. 8a illustrates the effect of extending the second heating impulse from time t = 0.95 to time t = 1.6 (thereby increasing the duration from 0.7 seconds to 1.35 seconds). As can be seen from the temperature/time plot II of Fig. 8a, this simply extends the time of exposure of the surfaces of the build-up to the sealing temperature and only a very slight decay of sealing temperature results. In each case the double impulse heating phase is followed by a cooling phase during which the temperature decays more rapidly.

By contrast, Figs. 9a and 9b show actual plots III and IV of temperature/time and current/time, respectively, for two separate conventional single impulse heating cycles in which on the one hand (the dotted line plot III) a sealing current of 150 amps is used and generates a temperature of the order of 280°C, and on the other hand (the continuous line plot IV) a lower temperature of 225°C results from a sealing current of 110 amps.

In order to compare the results of the process in accordance with the present invention with the process of the prior art, Figs. 10a and 10b superimpose the various temperature/time plots I and II of Figs. 8a and III and IV of Fig. 9a on Fig. 10a and the various corresponding current/time plots of Figs. 8b and 9b on Fig. 10b. As can be seen from

the current plots, a much higher peak current of 280 amps is observed in the first heating impulse of the double impulse cycle of the present invention, but this rapidly decays to a current of the order of 130 amps as a result of the resistance variation when a Hytemco wire is used. As a result, the heating current at the end of the first heating impulse of the cycle I or II in accordance with the present invention is virtually midway between the two separate heating current values shown in Fig. 9b. However, the temperature/time plots of Fig. 10a are interesting in that despite this much higher starting current in the heating phase of I and II the peak temperature attained is less than that with either of the two conventional plots III and IV, although it is attained more rapidly. This illustrates the advantage of the preferred arrangement in which a high temperature coefficient of resistance is evident in the alloy used for the heating wire for the two plots I and II, although the same basic advantage of the present invention would result if the resistance of the heating wire did not vary so dramatically with temperature (i.e. did not drop off so rapidly during the first heating impulse), except that in the latter case it would be necessary to avoid quite such a high initial temperature (i.e. quite such a high power level for the first heating impulse).

The effects of varying the duration of the second heating impulse in accordance with the present invention (previously illustrated on Figs. 8a and 8b) are interestingly compared with the results of changing the power level of the single impulse used in the conventional system illustrated in Figs. 9a and 9b, in that Fig. 10a shows that much more heat (represented by the area under plot II) can be imparted to the build-up of plies to be sealed when using the double impulse heating cycle of the present invention, than with the higher power level conventional single impulse (the area under the curve III), and with the advantage that the peak temperature of 210° applicable for plot II is much less than

the peak temperature of 284° applicable for the higher power level single impulse cycle. Thus the process in accordance with the present invention allows more heat to be input to the build-up (to achieve a good seal at the internal interface) with a lower peak temperature (giving reduced risk of contamination of the outer surfaces of the sealed build-up) than with the prior art single impulse system.

The Hytemco wire mentioned has been found to be particularly useful with the present invention in that it provides a measure of power adjustment with a constant voltage pulse. However, the same kind of improvement can be realised with wires of a lower temperature coefficient of resistance. We prefer the temperature coefficient of the wire to be at least 200×10^{-6} Ω/°C in order to derive the additional advantages appreciated from Figs. 5, 6, 12 and 13.

Figs. 11a and 11b illustrate the results of using alloys having different temperature coefficients of resistance for the heating element in the seal bar. The dotted line plot V in Fig. 11a shows the temperature/time characteristic for a heating ribbon of nichrome 50 alloy having a temperature coefficient of resistance of the order of 170×10^{-6} Ω/°C, whereas the solid line plot I (with the optional extension II of its second heating impulse) applies to a heating ribbon of Hytemco having a temperature coefficient of resistance of 4500×10^{-6} Ω/°C.

Fig. 11b shows the current/time plots from which it is evident that the first heating impulse for both the plot I and the plot V will be of equal duration. On the other hand, in terms of heat input to the seal bar (and therefore to the build-up of film plies to be sealed) it is clear from Fig. 11a that the area under the plot I during the first heating impulse (from time $t = 0$ to time $t = 0.25$ seconds) will be the same for plot I as for plot V.

The extension of the second heating impulse shown in Figs. 11a and 11b applies equally to the extension II of plot I for the Hytemco alloy and to the extension VI of plot V for

the nichrome 50 alloy. As can be seen from the temperature/time plots of Fig. 11a, the area under the curve of the extension will be the same regardless of which alloy is used.

It is therefore evident that the improvement in using a high temperature alloy is principally observed in the first heating impulse of the higher power level (cf plots I and V).

Although the above description illustrates the advantage of having several taps 33, 34, 35 and 36 for the primary of the step-down transformer 27, it should be understood that in practice the current amplitudes x and y, dependent upon the constant voltage values chosen for the 1st and 2nd impulses of the heating phase, are defined in order to achieve the required temperature values in the specific seal wire so that these parameters will remain valid (and do not need to be changed) unless the thermal characteristics of the seal bar are deliberately altered in some way (for substantially modifying the type and dimensions of the wire and/or the insulating tapes 19 and 21).

The consequence of changing the primary tap of the step-down transformer 27 is to alter the value of temperature T_s to be taken as the sealing temperature. In other words, when using a plastic material with a lower sealing temperature it is possible to select an appropriately different tap for the primary voltage in the transformer 27.

CLAIMS

1. A process for heat sealing thermoplastic film plies comprising clamping the film plies in contact with one another, between two clamping surfaces along a seal region; applying to at least one of the clamping surfaces a first electric heating impulse of a first power level while maintaining the clamping action, in order to obtain a temperature which is at least equal to the sealing temperature (as hereinbefore defined) of the film plies to be sealed, and less than the degradation temperature of the film; then immediately applying a second electric heating impulse of a second power level less than said first power level, to maintain a temperature which is at least as great as said sealing temperature again while maintaining the clamping action; and releasing the clamping action by separating the clamping surfaces from one another.

2. A process according to Claim 1 and including the step of maintaining the clamping action, after the second heating phase, while allowing the film plies to cool in their sealed condition.

3. A process according to either of the preceding claims, wherein said first and second heating impulses are each carried out at a constant voltage, and the heating current is allowed to vary as a function of the variation of the resistance of the heating element with temperature.

4. A process according to any one of the preceding claims, wherein the temperature coefficient of resistance of the electroconductive heating element is in excess of $200 \times 10^{-6} \Omega/^{\circ}C$ whereby the heating current will during said first heating impulse initially rise to a maximum at the start of the first heating impulse and then reduce, and will during the second heating impulse maintain a substantially

constant value through the majority of the duration of said second heating impulse.

5. A heat sealing process substantially as hereinbefore described with reference to examples 6, 7 or 8.

6. A heat sealing process substantially as hereinbefore described with reference to, and as illustrated in, Figs. 5 and 6, or Figs. 8a and 8b, or Figs. 11a and 11b, of the accompanying drawings.

7. Heat sealing apparatus comprising at least one heat seal bar having an electroconductive heating element; electrical energising means for said at least one heat seal bar; a control circuit defining for said electrical energising means a first heating impulse at a first power level, immediately followed by a second heating impulse at a second power level less than first power level; and means for clamping an array of thermoplastic film plies to be sealed, in contact with said at least one sealing bar during said first and seccnd heating impulses.

8. Heat sealing apparatus according to Claim 7 and further including means for cooling said at least one heat sealing bar during a cooling phase after said second heating phase and while clamping pressure is maintained holding said film against said at least one heat sealing bar.

9. Heat sealing apparatus according to Claim 7, wherein said electroconductive heating member has a temperature coefficient of resistance of greater than 200×10^{-6} Ω/°C.

10. A heat sealing bar having an electroconductive heating element having a temperature coefficient of resistance which is at least 200×10^{-6} Ω/°C.

11. Apparatus to Claim 9 or 10, wherein said electroconductive heating member is an alloy of nickel and iron having a temperature coefficient of resistance of about $4500 \times 10^{-6}\ \Omega/°C$.

12. Apparatus according to any one of Claims 7 to 11, wherein said electrical energising means include means defining a first ac voltage level during said first heating impulse, and a lower ac voltage level during said second heating impulse, while the current in said electroconductive heating element varies as a result of temperature-dependent variation of the resistance of said electroconductive heating element.

13. Apparatus according to any one of claims 7 to 12, wherein said electrical energising means comprise a step-down transformer the secondary of which is connected to said electroconductive heating element for energising the same; and a driver circuit connected to the primary of said step-down transformer and equipped with parallel paths of different impedances, both being connected to switching means for selecting the lower impedance path during said first heating impulse and the higher impedance path during said second heating impulse.

14. Apparatus according to claim 13, wherein said lower impedance path is connected across supply terminals and includes the primary of a further step-down transformer, wherein said higher impedance path includes the secondary of said step-down transformer, and wherein said switching means comprise switching relays in the higher and lower impedance paths for energising each of them separately while the other is de-energised.

15. Apparatus according to claim 15, wherein said switching relays are solid state switches which are energised by

respective square wave gating pulses displaced in time such that the descending front of said pulse gating the gating relay in said lower impedance path substantially coincides with the rising front of the gating pulse to the gating relay in said higher impedance path.

16. Apparatus according to claim 12, 13 or 14, wherein the first mentioned step-down transformer includes a plurality of primary taps which can be selected for varying the number of primary turns and hence for varying the current value in the secondary of said first step-down transformer during the two heating impulses.

17. Heat sealing means substantially as hereinbefore described with reference to, and as illustrated in, the accompanying drawings.

18. A heat seal bar constructed and adapted to operate substantially as hereinbefore described with reference to, and as illustrated in, the accompanying drawings.

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Databases (see below)
(i) UK Patent Office collections of GB, EP, WO and US patent specifications.

(ii) ONLINE DATABASES: WPI

Search Examiner
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Documents considered relevant following a search in respect of Claims :-
1-9,11-16

Categories of documents

X: Document indicating lack of novelty or of inventive step.

Y: Document indicating lack of inventive step if combined with one or more other documents of the same category.

A: Document indicating technological background and/or state of the art.

P: Document published on or after the declared priority date but before the filing date of the present application.

E: Patent document published on or after, but with priority date earlier than, the filing date of the present application.

&: Member of the same patent family; corresponding document.

Category	Identity of document and relevant passages	Relevant to claim(s)
X,Y	GB 1152593 (UNION CARBIDE) see page 2 lines 4-15	X:1-3,7,8 12 Y:4,9
X	US 5117613 (PFAFFMANN) see column 4 lines 30-51	1,2,7,8
A	US 4801784 (JENSEN) see column 1 lines 35-54	1,7
Y	US 3916148 (LAFLEUR) see column 3 lines 20-29	4,9
X	Patent Abstracts of Japan Vol. 16 No. 515 page 13 & JP 4-189724	1-3,7,8

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